Forest Research Branch

THE MICROENVIRONMENTS OCCUPIED BY SPRUCE AND FIR REGENERATION IN THE ROCKY MOUNTAINS

by

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ABSTRACT

In 1960 a microenvironmental study was made of spruce and fir regeneration on logged-over land in a subalpine forest in Alberta. The study shows that seedling growth is very slow, and abundant regeneration becomes established infrequently. Since most seedlings were found in cool, moist and shaded microenvironments and were growing in moisture retentive seedbeds, it is suggested that regeneration methods which provide shelter and conserve soil moisture be tested.

The Microenvironments Occupied by Spruce and Fir Regeneration in The Rocky Mountains[1]

by

R. J. DAY[2]

INTRODUCTION

The regeneration that follows logging of subalpine spruce-fir stands in the Crowsnest Forest of southern Alberta is generally unsatisfactory (Day and Duffy 1963). The slow re-establishment of hybrid spruce and alpine fir[3] seedlings on clear-cut and heavily partially-cut forest implies that the traditional logging practices do not produce suitable environments for germination and early development.

This study was designed to qualify the broad ecological results of an initial regeneration survey based on milliacre sampling (Day and Duffy 1963). Thus a separate field study was made of the microenvironments[4] occupied by individual spruce and fir seedlings that had become established on logged-over land. This permitted a much more precise evaluation of the seedling microenvironment than is possible when regeneration is sampled by milliacre quadrats.

Three things are essential for the establishment of natural regeneration:—

(1) Seed supply.

(2) Weather and microenvironments suitable for germination.

(3) Microenvironments suitable for survival and development of the seedlings.

The seed supply in the Crowsnest Forest is highly variable (Ackerman 1960)[5]. Logged-over land is well supplied in good seed years by the residual stand (Day and Duffy 1963).

The weather that follows snowmelt in late May or early June does not generally favour the germination or survival of either spruce or fir seedlings, owing to long clear days with the highest solar radiation intensities (Mateer 1955), low relative humidities and strong winds which produce soil surface drought and high soil surface temperatures (Day 1963). Low and irregular precipitation combined with periods of clear hot weather is a further hazard for seedling survival throughout the growing season. Slow early growth (from 6 to 7 inches in 10 years) restricts spruce and fir seedlings to air and soil layers near the surface which are subject to acute soil

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[3] Nomenclature follows E.H. Moss 1959. *Picea engelmannii* Parry X *P. glauca* (Moench) Voss., and *Abies lasiocarpa* (Hook.) Nutt.

[4] The microenvironment is the space above and below ground occupied by the organs of the seedling.

[5] Ackerman, R.F. 1960 — Reproduction of subalpine spruce after clear cutting, scarification and broadcast burning. Dept. Forestry, Canada, For. Res. Br., Unpub. MS.

moisture depletion and extremes of high (and low) temperature. Such conditions complicate the problem of obtaining natural regeneration in exposed clear-cut areas and in years with normal weather the regeneration is likely to be confined to a small number of moist microenvironments.

DESCRIPTION OF THE AREA

The Crowsnest Forest of southwest Alberta is in both the Subalpine and Montane Forest Regions (Rowe 1959). This study was carried out in two representative subalpine mountain valleys between 4,500 and 6,500 feet elevation. These valleys are of glacial origin with fast flowing streams draining from the rugged mountains of the Continental Divide a few miles to the west. The logged-over areas sampled were near-flat valley bottom alluvium and the adjacent moderate to steep till slopes. All these areas had been felled from 5 to 20 years before the study was made in 1960.

The region is characterised by great climatic variability caused by the extreme physical relief and the clarity of the atmosphere at high elevation. Within the altitude range of this study mean annual precipitation varies from 18 to 47 inches in the forest, with about 72 per cent falling as snow between October 31 and May 1. Snowmelt initiates the growing season between May 14 and June 21 according to local terrain and climate. Frosts are common on clear nights throughout the summer and frequent and severe frosts in late August and early September terminate the growing season. Thus even without drought the growing season is generally only approximately 100 days. Though the air temperature rarely exceeds 90° F. during the growing season, low day-time relative humidities of 10 to 20 per cent, low night-time relative humidities caused by chinook winds, and high soil surface temperatures in clear weather often combine to desiccate the soil surface. Surface temperatures of dry seedbeds commonly rise over 130°F. for periods of several hours and may reach maxima of 170°F.

The topography, geology, soils and climate of the region are fully described by Day and Duffy (1963).

METHODS

Representative logged-over areas were selected on each of seven physiographic site types (Day and Duffy 1963) in the two mountain valleys. Circular 1/500-acre plots (5.3 feet radius) were systematically located at the intersections of a 1-chain grid on each site type. Sampling by plots proceeded until 100 seedlings had been described on each of the seven site types in each valley. Thus the microenvironments of 1,400 seedlings (602 spruce and 798 fir) were described for analysis by machine processing. The selection of equal sites in each valley was to ensure that the ground sampled was comparable. Sampling within sites was not designed to demonstrate site-regeneration differences which are discussed by Day and Duffy (1963).

The following records were taken for each seedling:—

In The Field

(1) **Identification number.**

(2) **Valley** — Lynx or Lost Creek.

(3) **Site type.**

(4) **Residual stand** — the proportion of the residual stand (based on the number of trees) within 1 chain of the plot was recorded as:
  (a) no residual stand, fully open.
  (b) 1 - 10 per cent residual stand.
  (c) 11 - 25 per cent residual stand.
  (d) 26 - 50 per cent residual stand.
  (e) 51 - 100 per cent residual stand.

(5) **Species** — Spruce and fir alone were sampled.

(6) **Injury** — Bark necroses on the main stem and the direction the canker (or cankers) faced were recorded.

(7) **Seedbed** — Six types were recognized:
  (a) pure mineral soil.
  (b) mineral soil mixed with humus. This consisted mainly of A_h horizon material.
  (c) L. humus (litter).
  (d) F. and H. humus (fermentation and humification organic layers).
  (e) decayed wood of all types.
  (f) live moss. This was usually *Hylocomium splendens* (Hewg.) B. & S. or *Pleurozium schreberi* (Brid.) Mitt[1].

(8) **Depth to mineral soil** — The thickness of the organic layer was recorded in inches.

(9) **Moisture status of the root zone** — Sampling was confined to the driest months of July and August to assess the relative abundance of the two species in relation to soil moisture status during the dry season. The following records were made:
  (a) wet — water either dripped or could be easily squeezed from soil.
  (b) moist — the soil was moist to the touch and remained plastic when kneaded leaving a slight film of moisture on the skin.
  (c) damp — the soil felt damp and was semi-plastic when kneaded.
  (d) dry — the soil felt dry and was either powdery or crumbled to powder when handled.

(10) **Microslope** — The direction of the slope of the ground surface in each seedling microenvironment was noted and the surface recorded as:
  (a) flat, 0 to 5 per cent.
  (b) gentle, 6 to 10 per cent.
  (c) moderate, 11 to 20 per cent.
  (d) steep, 21 per cent or more.

[1] Nomenclature follows Watson 1959.

(11) **Shade** — The diurnal arc of the summer sun was established for each seedling. The main object, shading the seedling, was recorded as:

(a) tree, (b) shrub, (c) tall herb, (d) short herb.

(e) stump or log, (f) ground hummock or hollow.

The duration of the shade was recorded as:

(a) no shade.

(b) intermittent and less than 10 per cent of the day.

(c) 11 to 25 per cent of the day.

(d) 26 to 50 per cent of the day.

(f) 51 to 100 per cent of the day.

The intensity of shade cast for any period during the day was recorded as:

(a) unshaded, (b) light, (c) medium, (d) heavy.

Each seedling was carefully lifted from the soil and preserved. The following measurements were made:

In The Laboratory

(1) Shoot length in centimetres.

(2) Taproot length in centimetres.

(3) Length in centimetres of the longest lateral.

(4) Age by terminal node count.

(5) Age by thin sectioning and microscopic ring count.

Microscopic ring counting was the better method of age estimation and was used exclusively in this study.

ANALYSIS

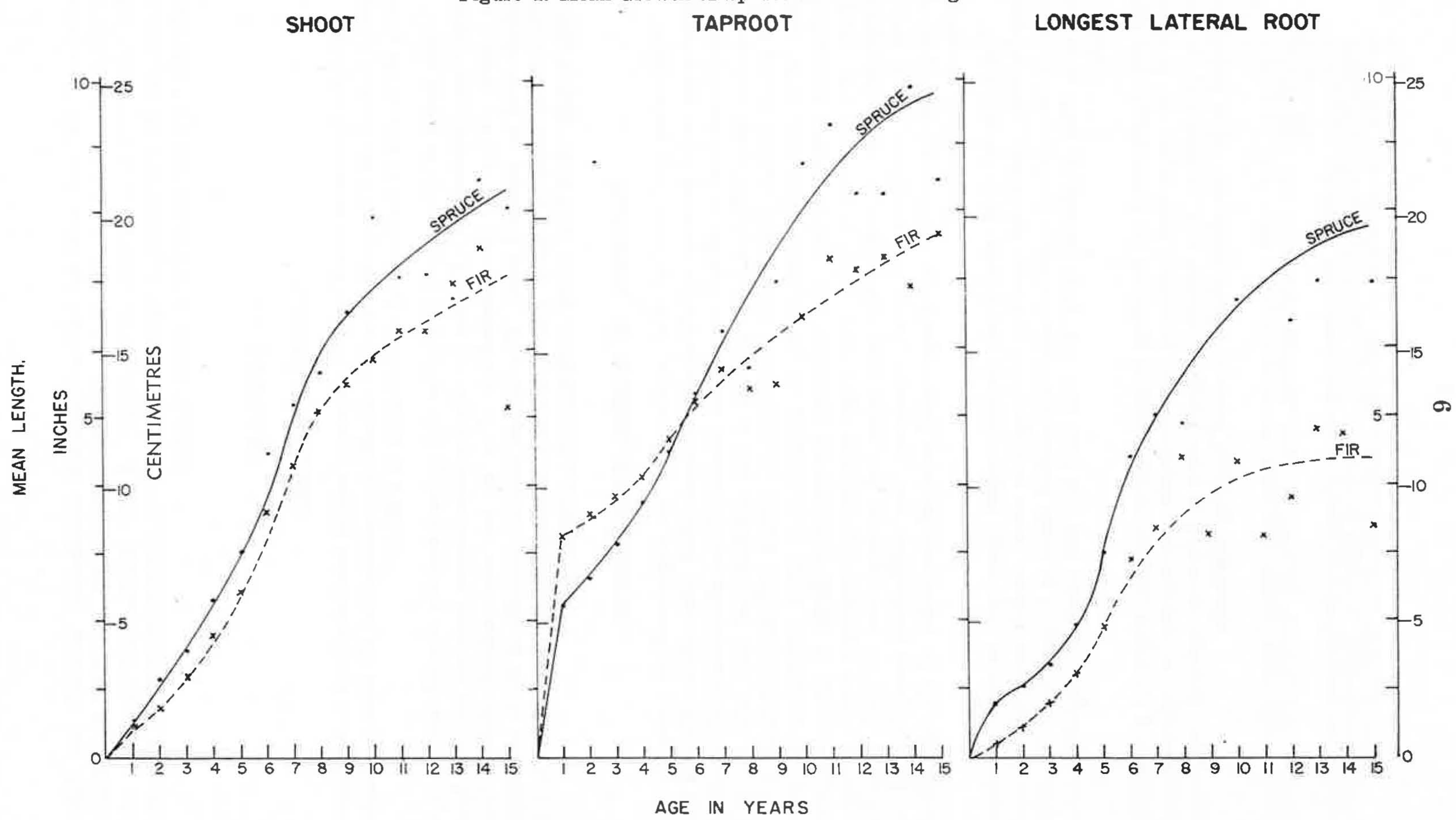
Machine processing was used to compile the field and laboratory data. The per cent abundance and growth of spruce and fir seedlings were related to individual and combinations of environmental factors. "t" tests (Snedecor 1956) were used to demonstrate significant differences. Because sampling was centred on individual seedlings in this study, per cent abundance does not denote relative areal abundance and is defined thus:—

Per Cent Abundance denotes the percentage of seedlings that were sampled in each of the classes used to describe each environmental factor (e.g. The per cent abundances of spruce seedlings in the soil moisture classes were:—wet 25.6, moist 37.5, damp, 35.8 and dry 1.1 totalling 100.0 per cent.).

In the analyses of the effects of shade, soil moisture and microslope, per cent abundance alone is used to indicate which of the classes of these factors were most favourable for spruce and fir seedling establishment and survival.

In the analyses of the effects of seedbed and residual stand, additional sampling to determine the area occupied by each seedbed and residual stand class permitted the results to be presented in terms of an index of

Figure 1. Mean Growth of Spruce and Fir Seedlings



abundance per unit area as well as per cent abundance. Though the index for abundance is the more precise unit for comparison, per cent abundance used alone gives a satisfactory picture of the shade, soil moisture and microslope environments occupied by the sparse regeneration that becomes established on the logged-over areas studied.

RESULTS

Growth of Seedlings

Graphs for mean shoot length, taproot length and length of the longest lateral root of all the spruce and fir seedlings sampled in all microenvironments are given in inches and centimetres in Figure 1.

The form of the curves is similar for spruce and fir though spruce has a slight size advantage (Figure 1). Fir has the longer taproot for the first five years, owing to the production of a 45 per cent longer radicle and juvenile root in the first year. The rate of taproot growth of fir is less than spruce in succeeding years. The shoot and longest lateral root of spruce is always longer than that of fir seedlings of a similar age.

Periodicity of Seedling Establishment

Fifty-nine per cent of the spruce and fir regeneration sampled on logged-over land became established between 1955 and 1957 (Figure 2). This large catch of seedlings cannot be related to an abundance of recently logged-over land because most of the areas studied had lain idle for five to ten years before 1955. The regeneration which became established between 1955 and 1957 appears to be related to a good seed crop in 1954 (Ackerman 1960)[1] which was followed by weather likely to favour germination and survival in 1955. The large number of seedlings which became established later in 1956 (the peak year for spruce) and in 1957 may be caused by a carryover of seed, however, the difficulties encountered in assessing the age of the seedlings could account for some of the spread of the curves in Figure 2[2].

Trials show that abundant seeding **alone** does not usually produce regeneration. Artificial seeding with spruce seed, which was 70 per cent viable, on 70 pairs of scarified and unscarified plots in Lynx Creek in 1959, 1960 and 1961 produced only 0.1, 0.5 and 0.1 per cent of seedlings respectively[3].

Thus the sharp peak of seedling establishment stands alone in a possible period of 20 years and indicates the probable periodicity of regeneration crops in the region. The results suggest that a five-year natural regeneration period is far too short under present logging methods.

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1 Ackerman, R.F. 1960 — Reproduction of subalpine spruce after clear cutting scarification and broad cast burning. Dept. of Forestry, Canada, For. Res. Br. Unpub. MS.

2 A separate sample of 450 spruce and fir seedlings collected in 1961 for detailed histological study gave similar curves to those in Figure 2. Both spruce and fir reached a peak abundance in 1955 with a rapid decrease in 1956 and 1957.

3 Unpublished work by the author.

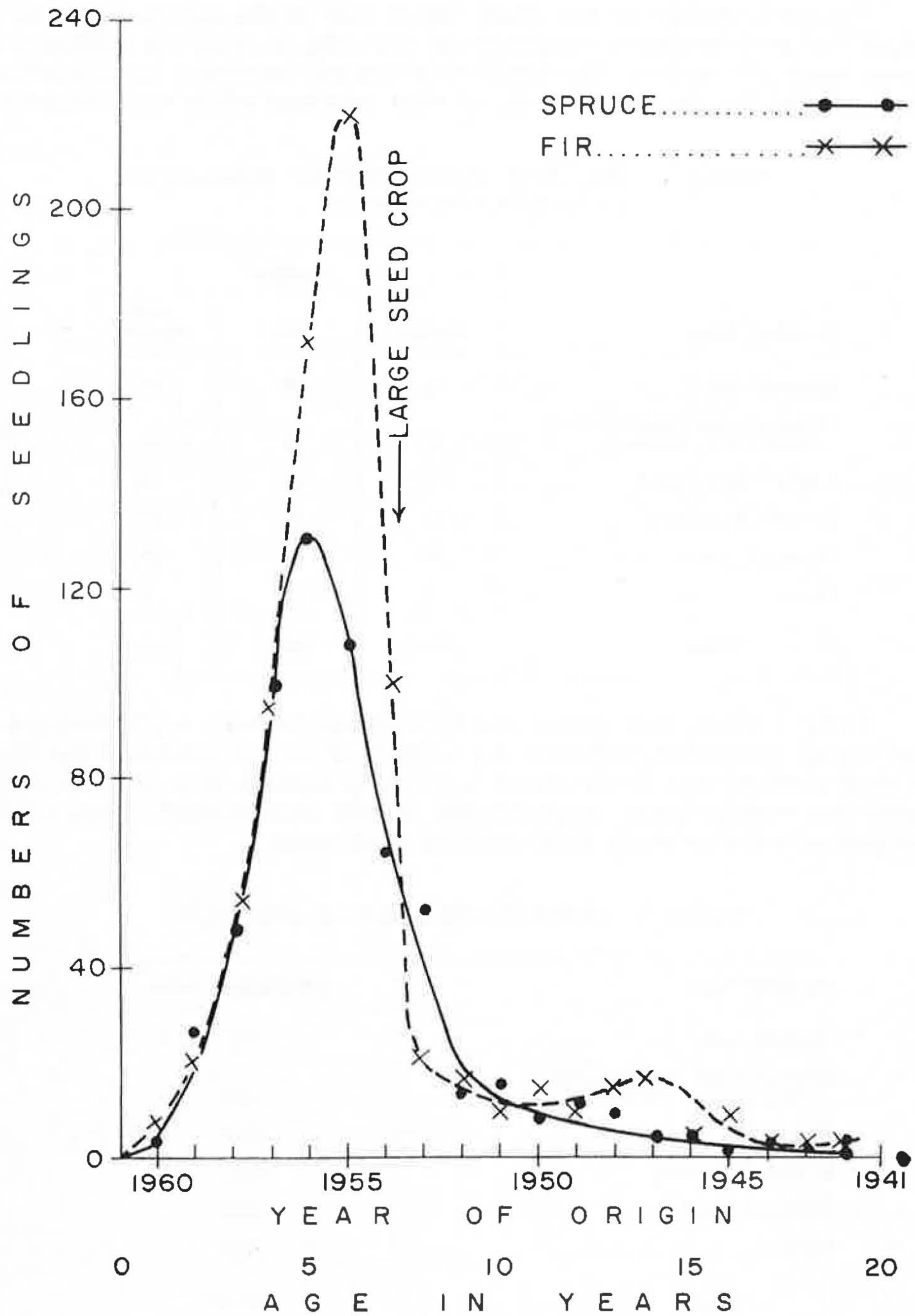

Figure 2. The Periodicity of Seedling Establishment

Microenvironmental Factors

Seedbed

The term seedbed in this study refers only to the soil surface which forms the germination environment for the seed. It does not include the layers below the surface. The depth of the organic layer was the only other parameter of the soil requirements of older seedlings which was measured.

TABLE 1. PER CENT ABUNDANCE OF SEEDLINGS ON VARIOUS SEEDBEDS

Seedbed Type	Species		
	Spruce	Fir	Both Species
Mineral soil	13	12	12
Mineral with incorporated humus (A_h horizon)	12	9	10
Litter (L. humus)	1	15	9
F. and H. humus	33	42	38
Decayed wood	34	20	26
Moss	7	2	5
Total	100%	100%	100%

Table 1 shows that spruce and fir seedlings became established on a wide range of seedbed materials. An estimate of the percentage of the area of each seedbed type in the region is given in Table 2. This is based upon 5,500 descriptions taken systematically on the sites studied at the intersections of a grid with the lines spaced a chain apart.

TABLE 2. PERCENTAGE AREA OF SEEDBEDS

Seedbed Type	Percentage Area
Mineral soil	15.5
Mineral with incorporated humus (A_h horizon)	4.9
Litter (L. humus)	34.8
F. and H. humus	25.4
Decayed wood	11.2
Moss	8.2
Total	100.0%

The per cent abundance of spruce and fir seedlings on each seedbed type relative to their per cent abundance on mineral soil is given in Table 3.

TABLE 3. INDICES* OF THE ABUNDANCE OF SPRUCE AND FIR SEEDLINGS ON SEEDBEDS OF EQUAL AREA.

Seedbed Type	Spruce	Fir	Both Species
Decayed wood	3.5	2.5	2.9
Mineral with incorporated humus (A_h horizon)	2.9	2.4	2.6
F. and H. humus	1.5	2.2	1.9
Moss	1.1	0.4	0.7
Mineral soil	1.0	1.0	1.0
Litter (L. humus)	0.04	0.6	0.3

* The index for abundance of each species (and of both when combined) on mineral soil is expressed as unity. Comparison between species is not possible.

Spruce and fir seedlings were most abundant per unit area on decayed wood, mineral soil with incorporated humus and F. and H. humus (Table 3). Seedlings of both species had become established in similar proportions on the various seedbeds even though the range of indices for abundance is greater for spruce than for fir. This suggests that spruce is more specific to seedbed type than fir. The heavier seed and longer taproot (radicle) of fir is a direct advantage for its establishment on droughty.materials (see page 7). This is substantiated by the superior representation of fir on litter. The indices for abundance of seedlings on the various seedbed types probably correspond to their moisture status during the dry months. Recent work in the Crowsnest Forest (Day 1963) has shown that well-decayed wood remains moist throughout the growing season, and in the shade F. and H. humus and mineral soil with incorporated humus are more water retentive than the common sandy loam soils.

Curves for the per cent abundance of spruce and fir seedlings on bare mineral soil and organic seedbeds of various depths are shown in Figure 3. A comparison of these curves with the curve for the per cent area of the various seedbed depth classes[1] (Figure 3) indicates the suitability of each depth of organic matter for the establishment of spruce and fir seedlings.

Spruce and fir regeneration is moderately well established on mineral soil, is poorly established on organic horizons up to 3 inches deep and is most abundant on soils with deep organic horizons. The regeneration on mineral soil occurs mainly on logging roads which have been cut into hillsides. These roadbeds generally lie well below the original soil surface and receive soil moisture percolating downslope. Regeneration on roadbeds in the flat valley bottom is sparse by comparison.

[1] The proportional area of bare mineral soil and organic seedbeds of various depths given in Figure 3 is based upon 5,500 systematic seedbed samples (see page 7).

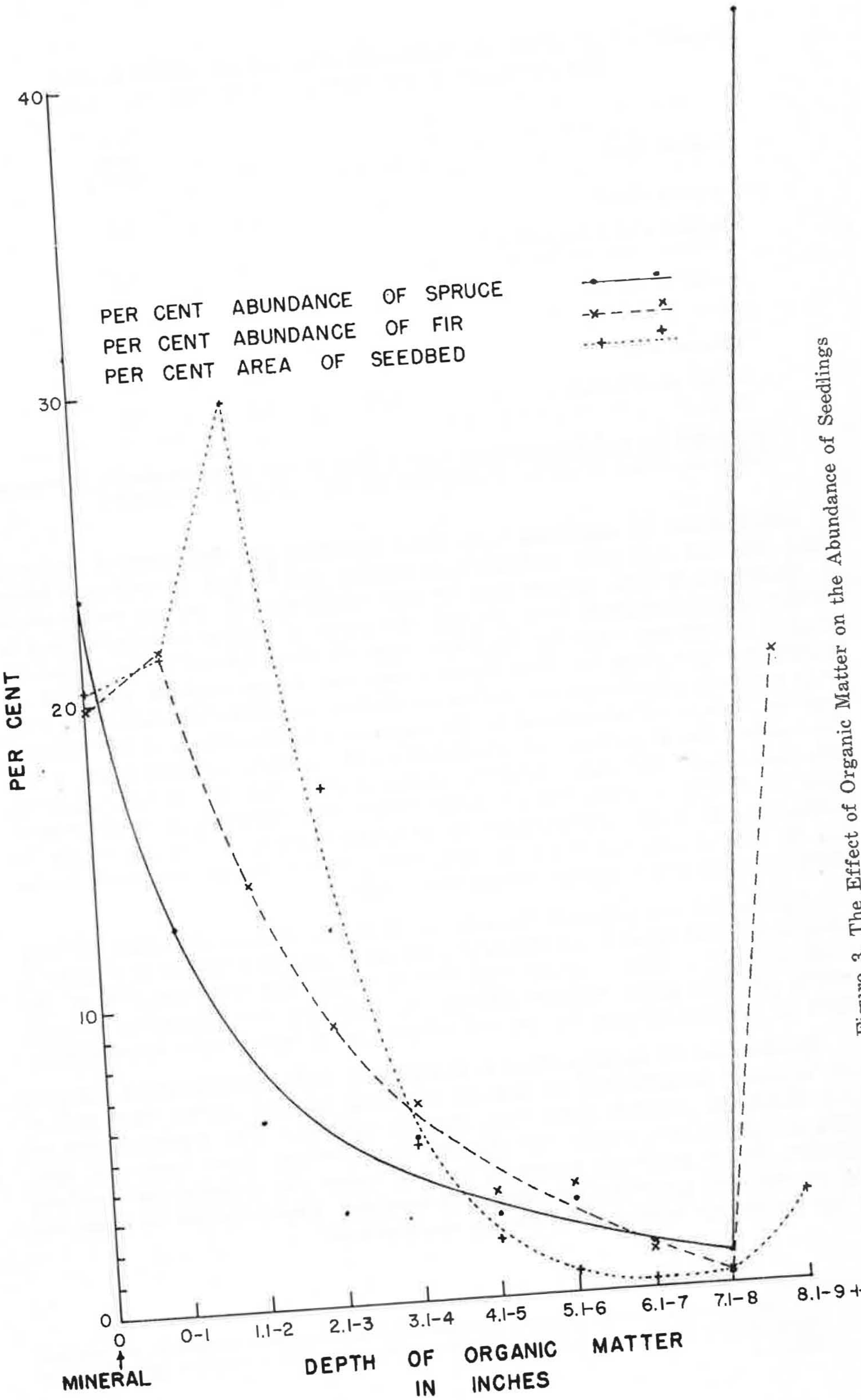

Figure 3. The Effect of Organic Matter on the Abundance of Seedlings

Soils with more than 4 inches of organic matter extend over less than 6 per cent of the area (Figure 3) and are usually confined to moist sites. Most organic layers more than 9 inches deep are in fact large well-decomposed logs and stumps which are very water retentive (Day 1963). This class of material must provide the most favourable soil environment for the establishment of seedlings, for though it covers less than 3 per cent of the area, it supports 42 per cent of the spruce and 20 per cent of the fir regeneration.

The mean shoot, taproot and longest lateral root lengths for the 4 to 6 year-old spruce and fir seedlings growing on the various seedbed types are given in Table 4. This age class was used for comparisons because it constituted 59 per cent of the regeneration (see page 10).

The "t" tests (Snedecor 1956) for regeneration on the various seedbed types in Table 4 show that spruce has a significantly longer shoot when growing on decayed wood than on mineral soil. Taproot development was significantly better on decayed wood and on mineral soil with incorporated humus than on F. and H. humus. Lateral root development was best on decayed wood. Observations show that spruce seedlings produce extensive lateral roots in rotten logs and extensive tap root systems in rotten stumps. Such roots run parallel to the tracheids along planes of weakness in the wood.

Fir seedlings on both mineral seedbed types develop shoots that are longer and are significantly different from those developed on all other seedbeds. Taproot development was poorest on F. and H. humus. Lateral root development was poorest on litter and on F. and H. humus.

TABLE 4. MEAN GROWTH OF 4 to 6 YEAR-OLD SPRUCE AND FIR SEEDLINGS ON VARIOUS SEEDBEDS

Seedbed Type	Spruce Shoot	Spruce Tap-root	Spruce Longest Lateral Root	Fir Shoot	Fir Tap-root	Fir Longest Lateral Root
	(centimetres)			(centimetres)		
Mineral soil	7.2	12.0	7.5	9.1	14.1	8.4
Mineral with humus incorporated	8.0	11.7	7.1	8.7	12.9	6.3
Litter (L. humus)	*	*	*	6.9	12.0	4.3
F. and H. humus	8.3	9.9	6.4	6.8	11.0	4.7
Decayed wood	9.0	13.2	10.6	6.9	13.4	6.9
Moss	7.8	11.4	8.2	*	*	*
Mean growth of population	8.3	11.5	7.9	7.3	12.2	5.7

* No mean given because of inadequate sample.

Shade

The per cent abundance of spruce and fir seedlings shaded for any part of the day by various objects on logged-over land is given in Table 5. Though combinations of objects sometimes shaded single seedlings, only the object casting the most shade was recorded.

Nearly all the seedlings were growing in some shade. Less than 5 per cent were entirely in the open. Residual trees, short herbs, tall herbs and slash were the main objects casting shade.

The per cent abundance of spruce and fir seedlings under various shade intensity and duration classes are given in Tables 6 and 7.

TABLE 5. PER CENT ABUNDANCE OF SEEDLINGS SHADED BY VARIOUS OBJECTS

Object Casting Shade	Spruce	Fir
No shade	3.6	4.6
Hump	4.5	4.5
Stump or log	7.7	13.2
Branch slash	16.8	20.6
Shrubs	5.8	6.8
Tall herbs (50 cm plus)	12.5	8.8
Short herbs (0-50 cm)	22.4	14.3
Trees	26.7	27.2
Total	100.0%	100.0%

TABLE 6. PER CENT ABUNDANCE OF SPRUCE REGENERATION BY INTENSITY AND DURATION OF SHADE.

Shade Intensity	Per Cent Shade Duration*					
	None	0 - 10	11 - 25	26 - 50	51 - 100	Total
	(per cent abundance of seedlings)					
None	3.7	—	—	—	—	**3.7**
Light	—	12.3	4.6	2.1	3.2	**22.2**
Medium	—	0.3	6.0	13.6	14.6	**34.5**
Heavy	—	0.2	1.0	6.7	31.7	**39.6**
Total	3.7	12.8	11.6	22.4	49.5	100.0

* Per cent of the day in which shade was cast.

TABLE 7. PER CENT ABUNDANCE OF FIR REGENERATION BY INTENSITY AND DURATION OF SHADE

Shade Intensity	Per Cent Shade Duration*					
	None	0 - 10	11 - 25	26 - 50	51 - 100	Total
	(per cent abundance of seedlings)					
None	4.5	—	—	—	—	4.5
Light	—	12.2	3.4	0.9	1.8	18.3
Medium	—	0.3	6.0	9.6	15.2	31.1
Heavy	—	1.2	1.4	9.8	33.7	46.1
Total	4.5	13.7	10.8	20.3	50.7	100.0

* Per cent of the day in which shade was cast.

Approximately two-thirds of both the spruce and fir seedlings were growing under medium-to-heavy shade which lasted from 26 to 100 per cent of the day.

Any suggestion that most of the seedlings became established in the open after logging before the re-vegetation of the site is incorrect. From Table 5, 56 per cent of the spruce and 66 per cent of the fir became established in the shade of such semi-permanent features of the logging site as humps, stumps, logs, slash and residual trees. It is important to repeat that 59 per cent of the seedlings became established after the 1954 seed crop, from 5 to 10 years after most of the area was logged.

The growth of 4-to 6-year-old spruce and fir seedlings in relation to shade intensity is given in Tables 8 and 9.

TABLE 8. MEAN GROWTH OF 4 to 6-YEAR OLD SPRUCE AND FIR SEEDLINGS UNDER FOUR SHADE INTENSITIES

Shade Intensity	Spruce			Fir		
	Shoot Length	Taproot Length	Longest Lateral Length	Shoot Length	Taproot Length	Longest Lateral Length
	(centimetres)			(centimetres)		
None	8.0	15.7	6.5	8.7	17.6	10.8
Light	9.2	13.5	10.0	8.0	12.6	6.7
Medium	8.6	11.3	8.2	7.0	11.7	5.3
Heavy	8.0	10.2	6.4	7.1	11.9	5.1
Mean growth of population	8.3	11.5	7.9	7.3	12.2	5.7

TABLE 9. MEAN GROWTH OF 4 to 6-YEAR SPRUCE AND FIR SEEDLINGS IN FIVE SHADE DURATIONS

Shade Duration (per cent of day)	Spruce			Fir		
	Shoot Length	Taproot Length	Longest Lateral Length	Shoot Length	Taproot Length	Longest Lateral Length
	(centimetres)			(centimetres)		
None	8.0	15.7	6.5	8.7	17.6	10.8
0 - 10	8.2	14.1	10.0	8.1	13.0	7.1
11 - 25	9.3	11.9	8.9	8.3	12.6	5.8
26 - 50	8.3	10.7	7.4	8.2	13.0	6.9
51 - 100	8.1	10.7	7.3	6.4	11.2	4.4
Mean growth of population	8.3	11.5	7.9	7.3	12.2	5.7

The mean growth of fir shoots, taproots and lateral roots is generally reduced either by an increase in intensity or duration of shade. In contrast spruce develops a shorter shoot in exposed microenvironments than in those with either moderate shade intensity or duration. The formation of shorter shoots by spruce and the development of the longest tap root by spruce and fir seedlings in exposed microenvironments could be a response to drought.

The shoot length of spruce did not change significantly with variations in either shade intensity or duration. Differences in the growth of fir shoots were similarly non-significant, except in shade for 50 to 100 per cent of the day where the average shoot length was shorter than in other shade durations. Tap root growth of both species graded from microenvironments with no shade to those with heavy shade or shade for 50 to 100 per cent of the day. Most differences in tap root growth were significant.

The reduction in length of roots and shoots under heavy shade is probably caused by competition for moisture and nutrients with associated plants as well as the low level of light intensity. It was not possible to separate the effects of these factors of the environment in this study.

Microslope

The directions of microslope occupied by spruce and fir seedlings are given in Table 10.

Kerner (1871) and Kaempfert (1942) have demonstrated that the coolest slopes are the north, northwest and northeast; that the warmest slopes are the south, southwest and southeast; and that east and west slopes

TABLE 10. THE PER CENT ABUNDANCE OF SPRUCE AND FIR SEEDLINGS FOUND ON THE EIGHT MICROSLOPE ASPECTS

Microslope Aspect	Spruce	Fir
Northwest	14.7	13.1
North	26.9	17.0
Northeast	11.5	8.0
East	6.0	7.0
Southeast	3.9	11.7
South	8.8	11.9
Southwest	8.4	12.7
West	5.7	9.6
Flat ground*	14.1	9.0
Total	100.0%	100.0%

* Percentage of flat microenvironments.

lie in an intermediate range and are similar. Kaempfert's work shows that the eastern slope is cooler in the winter and warmer in the summer than the western slope.

Spruce seedlings were considerably more abundant on the cooler microslopes than on the warm and intermediate ones (Table 10). Though fir is best represented on the north and northwest microslopes there is less difference in per cent abundance between these and the warm and intermediate aspects. This suggests that spruce seedlings are more sensitive to aspect than fir and that spruce tends to be most abundant on cool microslopes.

A record of the pitch of the microslope showed that seedlings of both species occur on all degrees of slope. There is a slight tendency for seedlings to be more abundant on moderate and gentle slopes.

Residual Stand

The per cent of spruce and fir seedlings associated with various densities of residual stand is given in Table 11.

TABLE 11. PER CENT ABUNDANCE OF SPRUCE AND FIR SEEDLINGS BENEATH RESIDUAL STANDS

Residual Stand Density	Spruce	Fir	Per Cent Area of Residual Stands
(per cent)			
0	39.8	42.0	51.0
1 - 10	24.9	20.0	28.0
11 - 25	12.3	10.3	8.0
26 - 50	21.5	22.4	9.0
51 - 100	1.5	5.3	4.0
Total	100.0%	100.0%	100.0%

The per cent abundance of spruce and fir seedlings per unit area under various residual stand densities relative to their per cent abundance in the open expressed as an index is given in Table 12.

The index for abundance of spruce and fir seedlings tends to increase with increasing residual stand density up to 50 per cent. Above 50 per cent the index for abundance of spruce is poorer than in any other class. The index for abundance of fir is reduced under residual stands over 50 per cent density, but less severely than spruce. The greater index for abundance of seedlings under residual stands of 11 to 50 per cent indicates that a regeneration method which retained some trees to provide seed and shelter should be tested.

TABLE 12. INDICES* OF THE ABUNDANCE OF SPRUCE AND FIR SEEDLINGS UNDER RESIDUAL STANDS AND IN THE OPEN

Residual Stand Density	Spruce	Fir
(per cent)		
0	1.0	1.0
1 - 10	1.1	0.9
11 - 25	2.0	1.6
26 - 50	3.1	3.0
51 - 100	0.5	1.6

* The index for abundance of each species in the open is expressed as unity. Comparison of indices between species is not possible.

The mean growth of shoots and tap roots of spruce and fir seedlings in relation to residual stand density is given in Table 13.

The shoot and tap root growth of both spruce and fir tend to decrease as the residual stand becomes denser. Shoot and tap root development is significantly better in the open than under the residual stand. Beneath the stand, differences in growth were not significant except for that of fir under the most dense stands. Spruce is probably similarly affected.

TABLE 13. MEAN GROWTH OF 4 to 6 YEAR OLD SPRUCE AND FIR SEEDLINGS UNDER RESIDUAL STANDS OF VARIOUS DENSITIES

Residual Stand Density	Spruce		Fir	
	Shoot Length	**Taproot Length**	**Shoot Length**	**Taproot Length**
(per cent)	(centimetres)		(centimetres)	
0	9.1	13.1	9.2	13.9
0 - 10	7.6	10.7	6.5	11.8
11 - 25	7.8	10.8	5.8	11.6
26 - 50	7.5	9.4	5.9	10.1
51 - 100	*	*	3.4	9.1
Mean growth of population	8.3	11.5	7.3	12.2

* Insufficient sample.

Moisture Status of the Root Horizon

The proportion of seedlings found in each of four soil moisture classes is given in Table 14.

TABLE 14. THE PER CENT ABUNDANCE OF SPRUCE AND FIR SEEDLINGS BY SOIL MOISTURE CLASSES

Moisture Status of Root Zone (July - August 1960)	Spruce	Fir
Wet	25.6	7.1
Moist	37.5	34.2
Damp	35.8	56.4
Dry	1.1	2.3
Total	100.0%	100.0%

Most spruce and fir seedlings had become established in microenvironments that retained some soil moisture during the critically dry summer of 1960 even though soil surface drought was apparently widespread. Young seedlings do not appear to be drought resistant for they generally only survive where there is a continued supply of soil moisture throughout the growing season. The greater per cent abundance of spruce over fir in moist microenvironments (Table 14) suggests that spruce is more dependent on soil moisture during the phase of establishment than fir which has both a heavier seed and a longer radicle.

Differences in root growth were not large between the various moisture classes. The best shoot and root growth of both species were recorded in microenvironments that had either damp or moist soil during the 1960 summer drought. Growth was poorest in dry soil.

Seedling Injuries

Bark necroses girdling part of the stem were found on 13 per cent of the spruce and 19 per cent of the fir seedlings sampled. Isolations from the necrotic tissues failed to produce consistantly either saprophytic or parasitic fungal mycelia or bacteria. As the fungi and bacteria which were cultured are common in healthy bark and wood, the injury probably originated mechanically.

The bark necroses may be initiated by drought and excessive surface temperatures (Day 1963) but further research is needed to confirm this theory. This study only shows that many of the injured seedlings were exposed and that two thirds of the necroses face the hot south and west aspects.

DISCUSSION

The study both confirms and amplifies the ecological results of the preliminary regeneration survey in the Crowsnest Forest (Day and Duffy 1963). It clearly shows that regeneration after logging is more abundant on moisture-retentive seedbeds in moist and shaded microenvironments.

The findings concur with the results of an experiment that demonstrated heating and drying of the soil surface can cause acute seedling mortality on dry exposed seedbeds in the Crowsnest Forest (Day 1963). Theory and the results of ecological research in the region suggest that regeneration cuttings be developed that will maintain soil surface moisture during the dry summer months and provide enough shade to permit the proper establishment of natural regeneration.

Information indicates that shade reduces the growth rate of both spruce and fir seedlings. Thus microenvironments most suited to germination and survival may not be best for later development. If shade is a necessity for early seedling development, it should be removed as soon as satisfactory stocking is achieved.

Research results do not support the general continuance of clear-cutting and heavy partial cutting followed by scarification of the ground. Examples are required that illustrate alternative regeneration methods. Possibly scarification before logging or simple strip or uniform shelterwood fellings (Troup 1955) could be tried to stimulate regeneration especially in the drier areas. Climatic variation is so great in the subalpine region that a number of regeneration methods will be necessary if all sites are to be satisfactorily regenerated.

SUMMARY

In 1960 a study was made of the microenvironments occupied by spruce and fir seedlings in the Crowsnest Forest, located in the Subalpine Region of southern Alberta. Some of the important results are:

(1) Spruce and fir seedlings grow very slowly in the region. The growth of spruce is slightly better than fir.

(2) During a 20-year logging period only a single peak of regeneration occurred. This followed a heavy seed crop in 1954 and favourable weather in 1955.

(3) Most of the spruce and fir seedlings had become established in moist and shaded microenvironments. Shaded decayed wood, mineral soil with incorporated humus, and F. and H. humus were the best seedbeds. Regeneration on organic matter was prolific where this exceeded four inches depth. Soil moisture appears to be the most important environmental factor controlling the establishment of regeneration in the region.

(4) Most of the spruce seedlings growing on sloping ground were on cool microslope aspects. Fir is able to become established in hotter and drier conditions and was equally represented on some warm microslope aspects.

(5) Approximately a third of the seedlings of both species occurred in microenvironments with heavy shade for 50 to 100 per cent of the day. The suggestion that the regeneration became established in the open immediately after logging is discounted; most of the seedlings were shaded by trees, slash, logs, stumps and humps. More than half the seedlings examined became established after the 1954 seed crop long after many of the areas were logged.

(6) Both spruce and fir regeneration increase considerably in abundance with increasing residual stand density up to 50 per cent.

(7) The results suggest that regeneration cuttings which provide shelter for the regeneration should be tested.

SOMMAIRE

En 1960, les conditions régnant dans de petites aires peuplées de semis d'épinette et de sapin dans la forêt de Crowsnest, qui se trouve dans la Région Subalpine de l'Alberta méridional, ont fait l'objet d'une étude. Les données les plus importantes recueillies au cours de l'étude sont les suivantes:

(1) les semis d'épinette et de sapin croissent très lentement dans la région. La croissance de l'épinette est un peu plus rapide que celle du sapin.

(2) Au cours de 20 ans de bûcheronnage, une seule période de pointe a favorisé la régénération. Cette régénération est attribuable à une grande abondance de semences en 1954 et à des conditions atmosphériques favorables en 1955.

(3) La plupart des semis d'épinette et de sapin se sont établis dans des petites aires humides et ombrées. Le bois pourri à l'ombre, du sol minéral contenant de l'humus et de l'humus des horizons F et H constituaient les meilleurs terrains de germination. La régénération prolifère le mieux dans une couche de matières organiques de plus de quatre pouces de profondeur. Il semble que la teneur du sol en eau soit le facteur de milieu le plus important, en ce qui concerne l'établissement de la régénération dans la région.

(4) La plupart des semis d'épinette croissant sur terrain en pente se trouvaient sur de petites pentes peu exposées aux rayons solaires. Le sapin peut s'établir dans un milieu plus chaud et plus sec; il pousse assez bien sur certaines micropentes bien ensoleillées.

(5) A peu près le tiers des semis des deux essences se rencontrent dans les petites aires fortement ombragées pendant 50 à 100 p. 100 de la journée. Il a fallu écarter l'idée selon laquelle la régénération se serait établie à découvert immédiatement après le bûcheronnage; la plupart des semis étaient ombragés par des abatis, des bûches, des chicots et des accidents de terrain. Plus de la moitié des semis examinés se sont établis à la suite de l'ensemencement naturel de 1954, longtemps après le bûcheronnage, dans la plupart des aires étudiées.

(6) La régénération, tant chez le sapin que chez l'épinette, devient plus abondante dans les peuplements résiduels d'une densité d'au plus 50 p. 100.

(7) D'après les résultats de l'étude, il semble qu'il y aurait lieu de faire l'essai de coupes de régénération propres à assurer une certaine protection aux semis.

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